

NAVAL WAR COLLEGE
Newport, R.I.

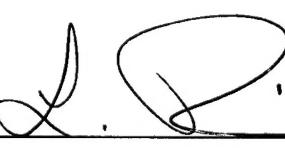
Technology's Impact on Command and Control: How Much does the
Operational Commander need?

By

L. Rice
CDR USN

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimitted

A paper submitted to the Faculty of the Naval War College in partial satisfaction of the requirements of the Department of Joint Military Operations. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Naval War College or the Department of the Navy.

Signature: 


14 November 1997

19970815 077

Paper directed by Captain Jackson
Chairman, Joint Military Operations Department

REPORT DOCUMENTATION PAGE

1. Report Security Classification: UNCLASSIFIED			
2. Security Classification Authority:			
3. Declassification/Downgrading Schedule:			
4. Distribution/Availability of Report: DISTRIBUTION STATEMENT A: APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.			
5. Name of Performing Organization: JOINT MILITARY OPERATIONS DEPARTMENT			
6. Office Symbol: C	7. Address: NAVAL WAR COLLEGE 686 CUSHING ROAD NEWPORT, RI 02841-1207		
8. Title (Include Security Classification): Technology's Impact On Command And Control: How Much Does The Operational Commander Need? (u)			
9. Personal Authors: RICE, LAWRENCE CDR, USN			
10. Type of Report: FINAL	11. Date of Report: 19 May 1997		
12. Page Count: 18			
13. Supplementary Notation: A paper submitted to the Faculty of the NWC in partial satisfaction of the requirements of the JMO Department. The contents of this paper reflect my own personal views and are not necessarily endorsed by the NWC or the Department of the Navy.			
14. Ten key words that relate to your paper: Command, Control, Technology, CTAPS, CAFMS, JTIDS, OPORD, OPLAN, Gulf War, Leadership			
15. Abstract: <p>Today's operational commander faces a daunting task. The increased complexity of the battlefield is changing the way we fight wars. Americans have frequently looked to technology to solve their problems, and command and control is no exception. Current systems are far better than those of a few years ago.</p> <p>As technology advances at an ever quickening pace, command and control systems strive to keep up. This rapid advance has a tendency to focus our attention on the systems themselves, rather than the command process. There are those that envision a day when future war fighters will sit in the Pentagon basement, select targets, and destroy them. While having that advanced technology is certainly advantageous, it eliminates the leadership of the operational commander.</p> <p>Another disadvantage of relying exclusively on technology to solve all our problems is that frequently, "demonstrated capability" is tested in a sterile, controlled environment. The end users often find that capability is less robust than advertised. Although technology will be a part of our future, operational commanders must use it to complement their leadership skills, not replace them.</p>			
16. Distribution / Availability of Abstract:	Unclassified X	Same As Rpt	DTIC Users
17. Abstract Security Classification: UNCLASSIFIED			
18. Name of Responsible Individual: CHAIRMAN, JOINT MILITARY OPERATIONS DEPARTMENT			
19. Telephone: 841-6461	20. Office Symbol: C		

ABSTRACT

Today's operational commander faces a daunting task. The increased complexity of the battlefield is changing the way we fight wars. Americans have frequently looked to technology to solve their problems, and command and control is no exception. Current systems are far better than those of a few years ago.

As technology advances at an ever quickening pace, command and control systems strive to keep up. This rapid advance has a tendency to focus our attention on the systems themselves, rather than the command process. There are those that envision a day when future war fighters will sit in the Pentagon basement, select targets, and destroy them. While having that advanced technology is certainly advantageous, it eliminates the leadership of the operational commander.

Another disadvantage of relying exclusively on technology to solve all our problems is that frequently, "demonstrated capability" is tested in a sterile, controlled environment. The end users often find that capability is less robust than advertised. Although technology will be a part of our future, operational commanders must use it to complement their leadership skills, not replace them.

INTRODUCTION

"The battlefield is a scene of constant chaos. The winner will be the one that best controls that chaos, both his own and that of his enemy."

Napoleon Bonaparte

As a key operational function, command and control is often considered the foundation of modern warfare. It is what operational commanders use to minimize the "fog" of war, to "control the chaos."

But warfare has changed dramatically since Napoleon's time. The increased complexity, space, and scope of the battlefield has reduced the time available for decision making. In response to this change, we routinely look to technology to provide the solution, as it has in the past. The pony express took days to deliver messages, the telegraph took minutes. As a fix for the millions of tons of "dumb" ordnance dropped in Vietnam, we developed "smart" weapons that were much more effective. To decrease pilot vulnerability, we developed cruise missiles and stealth. To improve command and control, we look to faster computers, fiber optics, increased bandwidth, and other technological improvements. These new systems must be interoperable, flexible, responsive, mobile, disciplines, survivable, and sustainable. Our track record in these areas is not 100%.

While it is clear that technology will play an important role in the future of command and control, it must respond to the demands of the war fighter. Additionally, claimed capabilities of technology often do not match up with wartime realities. Future operational commanders must ensure they do not use technology as a replacement for operational leadership.

COMMAND AND CONTROL

Command and control is often thought of as one entity. The military's use of the C2 (command and control) acronym brings even more validity to this thought. They are, however, two separate functions.

Command is the exercise of one's authority, responsibility, and leadership. It is formally defined as "the authority that a commander in the Armed Forces lawfully exercises over subordinates by virtue of rank or assignment. Command includes the authority and responsibility for effectively using available resources and for planning the employment of, organizing, directing, coordinating, and controlling military forces for the accomplishment of assigned missions. It also includes responsibility for health, welfare, morale and discipline of assigned personnel."¹ Command is the *process* that cuts through the "fog."

Control, on the other hand, is the means by which a commander guides the conduct of operations.² It is the *system* that cuts through the "fog." Fleet Marine Force Manual 3 Command and Control tells us "More than ever before, a command and control system is crucial to success and must support shorter decision cycles and instantaneous flexibility across vast distances of time and space." This is typical of today's publications. The emphasis is on the systems, not the process, not surprising, considering America's fascination with technology. A fascination that started long ago.

¹U.S. Joint Chiefs of Staff, Doctrine for Command, Control, Communications, and Computer (C4) Systems Support to Joint Operations (Washington: 1995), GL-4.

²U.S. Navy Dept., Naval Doctrine Publication 6, Naval Command and Control (Washington: 1995), 9.

The American Civil War has been cited as a Revolution in Military Affairs (RMA) due to the first use of railroads and telegraphs. Imagine how excited commanders were by the telegraph. Their orders could be received by wire in a matter of minutes instead of days by courier. Imagine their dismay when their dependence on this new technology backfired when the wires were cut (early information warfare?). During Stonewall Jackson's Shenandoah Valley Campaign in 1862, President Lincoln sat in the War Department telegraph office and fired off telegrams to his generals, ordering them all over the battlefield.³ The telegraph the commanders had fallen in love with had come back to haunt them. This was the epitome of centralized command *and* execution. They were too dependent on a system, rather than a process. We too have become more dependent on systems.

In Desert Storm, we used 35,000 frequencies. In one day, United States forces generated 152,000 messages and made over 700,000 phone calls.⁴ The massive command and control system in place enabled the coalition partners this luxury. By comparison, Admiral Horatio Nelson used only three general flag hoists to win the Battle of Trafalgar.⁵ One could certainly argue that the changing nature of war requires more constant communication. While true to some extent, it is obvious that no one commander could read, analyze, and react to 152,000 messages a day. Yet we continue to assume that the answer to command and control problems is to build a better system, rather than rely on subordinates better understanding the commander's intent.

³James M. McPherson, Battle Cry of Freedom (New York: Ballantine 1988), 457.

⁴U.S. Department of Defense, Conduct of the Persian Gulf War (Washington: 1992), K-26.

⁵Naval Doctrine Publication 6, 6.

John Boyd's famous OODA (Observe, Orient, Decide, Act) Loop has been used as a model of the decision and execution cycle for years. The idea behind it is that operational success is often determined by which commander can cycle through his loop the fastest. By acting so quickly, the victorious commander will cause his opponents OODA loop to collapse, paralyzing his decision making process.

Generated by a Korean War fighter pilot, the OODA Loop is deceptively simple. It also operates on the traditional hierarchical model of command and control, that is, commands moving up and down the chain of command. Improvements to this system have concentrated on speeding up the transmission and amount of data. The quicker data can be moved up and down the chain of command, the quicker the loop can be completed. In an effort to speed up this process, we are faced with an interesting dilemma, the more we rely on technology, the more we depend on it.

TECHNOLOGICAL IMPROVEMENTS

During the Gulf War, the joint forces air component commander (JFACC) tried to speed up the data transfer process by using a computer assisted force management system (CAFMS). In theory, it would allow the lengthy air tasking order (ATO) to be transmitted electronically to Air Force, Navy, Army, and Marine aviation units. Although the Navy was issued 5 CAFMS terminals in 1991, they were never able to receive the ATO due to "communication difficulties," later traced to super high frequency transmission limitations.⁶ The Army and Marines experienced

⁶James A Winnefeld, Joint Air Operations (Annapolis: Naval Institute Press 1993), 195.

similar problems. To work around the problem, the Navy had to dispatch an aircraft from the carrier to pick up a hard copy of the ATO. Twentieth century technology delivered via messenger. To fix the problem, the Contingency Theater Automated Planning System (CTAPS) was introduced. According to Major General Marcus Hurley, USAF, Director of Plans and Policy at Air Combat Command:

"A new command and control tool, CTAPS, replaces the automated system used in the Gulf War. CTAPS makes it easier for a JFACC to redirect sorties and missions even after the ATO is published and distributed since it allows real-time communications among operations staffs, including naval aviation aboard carriers."⁷

In the ongoing Operation Southern Watch, the daily ATO is transmitted without any difficulties. This does not mean, however, that the problem is solved. Operation Southern Watch has had the benefit of six years of fine tuning. During the recent *Rugged Nautilus* exercise in the Persian Gulf region, which focused on rapidly establishing a joint task force, with the JFACC onboard the USS Carl Vinson, the old problems of connectivity arose. Brigadier General Smith, Commander of the 4th Fighter Wing, said, "It took a while to make this system work, and I don't think any of us are convinced that we yet have the kind of communications that we need to do that as well as we would like."⁸ There appears to be a disconnect between the planners in Washington (Gen. Hurley) and the end users (Gen. Smith). In today's world of rapidly emerging threats, merely having the technology is not enough, it needs to work the first time, all the

⁷Marcus Hurley, "JFACC, Taking the Next Step," Joint Forces Quarterly, Spring 1995, 63.

⁸Robert K. Ackerman, "Air Force Pilots Engage Tactical Data Targets," Signal, November 1996, 19.

time. Although CTAPS represents only a small segment of the operational commander's concerns, the technological difficulties encountered span the inventory.

Another way to speed up the OODA loop is to change from a hierarchical system to a multiple access or distributed data system. This type of system distributes data electronically to all users at the same time, without human interface. The Joint Tactical Information Distribution System (JTIDS) provides this kind of flexible connectivity useful to the commander. JTIDS was designed to be a mobile, decentralized, receiver-oriented communications system characterized by wide-ranging connectivity between combat elements with different functions, command lines, parent services, and even languages (hence its NATO applicability).⁹ Each member of the net is assigned (by computer) a 7.8 millisecond time slot. In this slot is the unit's identity, position, fuel, ordnance, speed, heading, and altitude.

Originally designed exclusively for aircraft, a number of units are now JTIDS capable. Army Patriots, Marine Hawks, Navy AEGIS Cruisers, Air Force AWACS, and aircraft from over 5 countries all contribute to the net. Units in the JTIDS net are displayed as well as any information their sensors (usually radar) detect. The result is a comprehensive picture of the battlefield. Each operator can select as much information as they desire. Not only does this have a significant tactical usefulness, but the commander now has a complete and instant picture of operations. The observe and orient steps of the OODA loop are now almost instantaneous.

⁹Kenneth C. Allard, Command, Control, and the Common Defense (New Haven: Yale University Press 1990), 208.

In addition to JTIDS, the Army is using an Enhanced Position Location Reporting System (EPLRS) to transmit unit location ground tracks. The Marine Corps uses the Position Location Reporting System (PLRS) for the same purpose.¹⁰ The fusion of JTIDS, PLRS, and EPLRS data provide the operational commander with a real time, three dimensional picture of the battlefield. The organic relay capability of each JTIDS unit allows the entire electronic attack-resistant picture to be seen over 1200 miles away. During previous Joint Warrior Interoperability Demonstration (JWID) exercises, Marine Corps units (using PLRS) in Okinawa, Japan; Army units (using EPLRS) in Fort Hood, Texas; and Navy surface vessels at sea (using JTIDS) in the Western Pacific linked together to provide situational awareness for the joint task force commander.¹¹ No longer will the commander have to rely on the "old style" hierarchical communication systems to send him information, he can *see* it himself.

All these capabilities will provide new dilemmas for the commander. The current doctrine of centralized command and decentralized execution could be changed to centralized command *and* execution. Already the predictions are arriving. *The Economist* prognosticates that "Such a system would allow a commander to watch a screen displaying everything going on in a battle, select targets and destroy them by pressing a button."¹² Adm. Archie Clemins, Commander-in-Chief, U. S. Pacific Fleet, "explained that his concept of information systems at sea is to engage in combat and to run

¹⁰Clarence A. Robinson, Jr., "Commanders Observe, Control Distant Real-Time Maneuvers," Signal, June 1996, 51.

¹¹Ibid., 52.

¹²"The Future Of Warfare" The Economist, 8 March 1997, 21.

the ship from a single personal-computer-based system.¹³ Proponents claim that the *nature* of warfare could change.

Before all the military's eggs go into the technology basket, these latest systems need to be put under the microscope. Although JTIDS has demonstrated its tactical usefulness among same-service units, it presents interoperability and compatibility problems for the joint operational commander.

The Navy units send data over JTIDS via a Distributed Time Division Multiple Access (DTDMA). The Air Force uses a Time Division Multiple Access (TDMA). The difference between the two is beyond the scope of this paper, but suffice to say that the message forms are radically different. So different, in fact, that they are unable to communicate with each other unless data translators are used, or special training networks set up. These translators are also used when sending the information to Patriot and Hawk batteries. Unfortunately, due to small system incompatibilities, these data translators are not 100% effective.

During a recent All Services Combat Identification Evaluation Test (ASCIET '95) in Gulfport, Mississippi, these "incompatibilities" resulted in dual tracks being sent where there was only one, no tracks sent where there was one, and even friendly units switching their "track" with the enemy's.¹⁴ This "track" switching resulted in friendly units being engaged by Patriot batteries when returning to base, thinking they were hostile. JTIDS interoperability difficulties were not limited to one exercise. During *Roving*

¹³C. Norman Wood, "Secure Information Demonstrations Stimulate Modern Military Thinking," Signal, March 1997, 15.

¹⁴Marine Air Control Squadron 6. "Joint Tactical Information Distribution System (JTIDS)." Joint Universal Lessons Learned Database, September 1995.

Sands '95 in the New Mexico and Texas desert, the first lesson learned published by the USS Curtis Wilbur (DDG-54), was "Multiservice link connectivity does not currently exist."¹⁵ The Curtis Wilbur is one of the Navy's newest "Arleigh Burke" class guided missile destroyers outfitted with the latest electronics.

JTIDS was first employed in an AWACS aircraft in 1983. Despite 14 years of calibration, it is still not completely integrated. The architectural problems are supposed to be solved by 1999 with improved software and a follow on system. How long it will take to work the bugs out of the new system is unknown. While JTIDS remains an invaluable tool for the tactical war fighter, its use by the operational commander remains in question.

JTIDS, CTAPS, and CAFMS are all examples of high technology that could use a little fine tuning. Not all our problems are with such systems. Sometimes, we have difficulties with even the most basic of tasks. During a Joint Task Force Exercise (*CJTFEX '96/Purple Star*), basic communications were backlogged with over 700 signals in the que. One of the participants, HMS ILLUSTRIOUS, received the same message 80 times.¹⁶

Have we been so caught up in trying to improve the technology, that we have forgotten to ask, "Is this really what we want?" Do we envision wars of the future being fought at some distant location by computer, with friendly and enemy tracks linked by remote and space based sensors? While some commanders might argue that this "space invaders" method of

¹⁵COMUSNAVCENT. "Roving Sands 95." Joint Universal Lessons Learned Database, June 1996.

¹⁶CINCLANTFLT. "CJTFEX 96/Purple Star." Joint Universal Lessons Learned Database, November 1996.

warfare would save lives, it is optimistic to imagine an adversary, having learned Iraq's lesson, would be so accommodating. It would appear that the majority of effort has gone into improving the system, not the process.

Technology proponents could point to General Robert E. Lee's Gettysburg campaign as a reason to acquire more and better systems. They would argue that if Lee and his subordinate, General Richard S. Ewell had been in contact with each other, Lee's constant communication could have allowed Ewell to move on the North's position. There was, however, no constant contact, and thanks to the ambiguous order Lee gave to Ewell "to carry the hill occupied by the enemy, if he found it practicable," (Ewell didn't), the South lost the battle.¹⁷ Had Ewell and Lee had some sort of a portable telegraph, they could have ironed out their inconsistencies. But the real problem was not with the system, but the process. The "commander's intent" Lee gave to Ewell was lacking and open to interpretation. To take advantage of high tempo operations and an ever changing battlefield, each subordinate must understand the commander's desires.

NON-TECHNOLOGY ISSUES

While some would say that Civil War examples are too dated, the same lesson was again learned in the Gulf War. General Schwarzkopf was frustrated with the VII corps progress under LtGeneral Franks. The instantaneous satellite communications available did not speed up the corps' advance, only Schwarzkopf's frustration. In other words, the best control

¹⁷Naval Doctrine Publication 6, 58.

systems in the world do not necessarily mean the best command process. This is a lesson that we continually relearn.

This does not imply that technology will not play an important role in the future, it already does today. An over dependence, however, can be fatal. If future opponents decide to fight "asymmetrically" like the North Vietnamese did in Southeast Asia, it will negate our technological edge.¹⁸ The United States will bring in cruise missiles and laser guided bombs while the enemy hides in underground caves and travels on remote mountain trails. What can the commander do to combat this asymmetric fight? The same thing he has done for centuries.

"Lord Nelson did not win at Trafalgar because his plan was great, although his plan was great. He won because his subordinate commanders thoroughly understood that plan and their place in it well in advance of planned execution."¹⁹

Lord Nelson's subordinates understood the plan and General Lee's did not. Was technology the reason? Certainly not. Lord Nelson understood the value of his subordinates having a clear picture of the overall plan. The obvious problem was that each commander had a different style in communicating his plan. To alleviate this inconsistency, numerous methods were developed to produce a standardized format. The Operation Order (OPORD) was developed as the method to pass on "the plan."

"There is an aphorism that plans are worthless, but planning is indispensable."²⁰ In the Gulf War, four Operations Plans (OPLANS) were

¹⁸"Getting Ready For The Wrong War?" U.S. News & World Report, 12 May 1997, 32.

¹⁹Naval Doctrine Publication 6, 58.

²⁰Conduct of the Persian Gulf War, I-7.

developed. These OPLANS were combined to form the final OPORD. They had to be continually changed based on who the coalition forces added to their ranks. The final OPORD was distributed in English and Arabic so that everyone would understand the *commander's intent*. This final OPORD was signed on 29 November and provided all the necessary information. Ironically, the task which took the most time was not the planning itself, but the translation of the OPLAN to Arabic. "It (the OPLAN) required Arab officers with considerable operational experience and English proficiency to translate important instructions to reflect the *commander's intentions* accurately" (emphasis added).²¹

The coalition forces knew how important C2 was. One indication of this was the OPLAN's identification of the Iraqi C2 as a "center of gravity." During the initial air campaign, both the system and the process were targeted. C2 nodes and technological capabilities were attacked as well as their leadership. As the air campaign progressed, the coalition forces realized that attacking the technology would be difficult. Redundant systems tied together with land lines (underground fiber optic cable) proved impossible to completely destroy. Systems designed to relay orders to the troops in the field, however, proved easy to neutralize. The majority of the troops in the field were so used to receiving orders to do everything, that when these orders did not arrive, they were paralyzed. We could argue had Iraq fielded a more technologically advanced C2 system, they would not have experienced so many difficulties. Again, even the best technology would not have helped their lack of a comprehensive plan. Iraq had become

²¹Ibid., I-19.

too reliant on the systems and ignored the process. Operational Commanders must not fall into the same trap.

CONCLUSION

Command and control pervades all aspects of joint and combined warfare. It combines the *process* of command and the *systems* of control. While the process of command has not changed significantly over the last few centuries, the control systems have changed dramatically. Technology has not only changed the way wars are fought, it permeates the planning process. Joint publication 6-0, Doctrine for Command, Control, Communications, and Computer Systems Support to Joint Operations, reminds us, however, that "No amount of technology can replace the face-to-face exchange of information between commanders."

One of the problems with an over reliance on technology is that even "seemingly simple" hierarchical communication systems can fail to work as advertised. During the Gulf War, "A comprehensive C3 interoperability plan between services and other defense agencies had to be constructed with many workarounds."²² Despite seven years of development on this plan, joint task force commanders are still experiencing difficulties trying to assemble the requisite nodes on short notice. Even though many senior officers point to CTAPS as a model for joint and combined, interoperable systems, its ability to be assembled quickly enough to meet the war fighters still needs attention.

²²Ibid., K-48.

If CTAPS is "seemingly simple," then a distributed data network like JTIDS is decidedly more complex. This increased complexity brings with it its own set of problems. The interoperability problems experienced by the network are still present despite an introduction of operational capability over 14 years ago. Thanks to its demonstrated tactical success, JTIDS is billed as a "proven" method of providing fused battlefield information to the commander. However, the capability to assemble a joint or combined network without extensive preparation does not exist. The technical difficulties experienced by the network are not insurmountable. It is logical to assume that follow on systems will solve the interoperability problems and actually be able to provide real-time, fused information to the commander. However, this information needs to be used as a tool, an addition to his leadership "kit," *not* a substitute.

As we look back through history at great operational commanders, much is said about their leadership. It is often the focus, as it should be, of our studies. Future operational commanders must be wary of any system that claims it can replace our leaders by completely eliminating "fog and friction."

"I think of command and control as two different things. . . I believe that the more control a senior places on a subordinate the less command capability he has. And the more a commander is capable of commanding, the less control he requires."

LtGen. Ernest C. Cheatham, U.S. Marine Corps (Retired), 1994²³

²³Naval Doctrine Publication 6, 10.

BIBLIOGRAPHY

Ackerman, Robert K. "Air Force Pilots Engage Tactical Data Targets." Signal, November 1996, 19-23.

Allard, Kenneth C. Command, Control, and the Common Defense. New Haven: Yale University Press, 1990.

Aspin, Les. Defense for a new era, lessons of the Persian Gulf War. Washington D.C.: U.S. Govt. Print. Off., 1992.

Boorda, Jeremy M. "Leading the Revolution in C4I." Joint Forces Quarterly, Autumn 1995, 14-17.

Casper, Lawrence, Irving Halter, Earl Power, Paul Selve, Thomas Steffens, and Lamar Willis. "Knowledge-Based Warfare: A Security Strategy for the Next Century." Joint Forces Quarterly, Autumn 1996, 81-89.

CINCLANTFLT. "CJTFEX 96/Purple Star." Joint Universal Lessons Learned Database. Washington, November 1996.

COMUSNAVCENT. "Roving Sands 95." Joint Universal Lessons Learned Database. Washington, June 1996.

"Getting Ready For The Wrong War?" U.S. News & World Report, 12 May 1997, 30-35.

Hurley, Marcus. "JFACC, Taking the Next Step," Joint Forces Quarterly, Spring 1995, 60-65.

Marine Air Control Squadron 6. "Joint Tactical Information Distribution System (JTIDS)." Joint Universal Lessons Learned Database. Washington, September 1995.

McPherson, James M. Battle Cry of Freedom. New York: Ballantine, 1988.

Robinson, Clarence A. Jr., "Commanders Observe, Control Distant Real-Time Maneuvers." Signal, June 1996, 51-54.

"The Future Of Warfare" The Economist, 8 March 1997, 21-23.

U.S. Department of Defense, Conduct of the Persian Gulf War. Washington: U.S. Govt. Print. Off., 1992.

U.S. Joint Chiefs of Staff. Doctrine for Command, Control, Communications, and Computer (C4) Systems Support to Joint Operations. Washington: U.S. Govt. Print. Off., 1995.

_____. Doctrine for Joint Operations. Washington: U.S. Govt. Print. Off., 1995.

_____. Doctrine for Planning Joint Operations. Washington: U.S. Govt. Print. Off., 1995.

_____. Joint Doctrine for Command and Control Warfare (C2W). Washington: U.S. Govt. Print. Off., 1995.

U.S. Navy Dept. Naval Doctrine Publication 6, Naval Command and Control. Washington: U.S. Govt. Print. Off., 1995.

Walsh, Edward J. "Navy Ship Designs Incorporate Sensors, Information Systems." Signal, December 1996, 41-43.

Winnefeld, James A. Joint Air Operations. Annapolis: Naval Institute Press, 1993.

Wood, C. Norman. "Secure Information Demonstrations Stimulate Modern Military Thinking." Signal, March 1997, 15.